Roller Mountable Asphalt Pavement Quality Indicator

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Asphalt density measurements have been traditionally used as an indication of roadway pavement quality. These measurements, however, have not been available in real time to make in-process corrections to the paving operation since the existing techniques require on the order of minutes (nuclear density gauge) to hours (core samples) to produce accurate density measurements. Traditional ground penetrating radar (GPR) techniques could also have limitations due to the changing properties of the hot mix asphalt pavement while it is being compacted. This paper describes a novel approach to measure, for the first time, the density of asphalt in real time using a differential microwave signal approach. Two antennas, one in front of a roller and another behind it, will measure reflected signals from the asphalt; the change in signal characteristic from the front to back of the roller will show to the operator the optimal compaction and density of the pavement. This technique will minimize the need to quantify the hot mix asphalt properties that change during the compaction process. Field studies show that this approach has potential.

INTRODUCTION

In order to rebuild and pave existing highways that show signs of cracking and significant deterioration, it is important to effectively control the paving process. Several people are involved in producing a quality asphalt pavement (e.g., design mix specifier, hot mix plant operator, QA/QC inspector, asphalt laying operator, and roller compactor operator) — but it is the roller operator's skill that ultimately determines the final quality of the compacted mat where its density determines the effectiveness of compaction. Only a carefully planned rolling pattern gives the uniformity and desired density. An under compacted asphalt mat is permeable to air and water which shortens the pavement life, while unnecessary extra passes may lead to over compaction and a reduction in air void content that can cause significant permanent deformation (*1*). The only way to know the most efficient rolling pattern is for the roller operator to monitor the asphalt density in real time.

Existing techniques have drawbacks. For example, the nuclear density gauge, which uses a gamma ray back scattering technique, requires proper calibration and several minutes to obtain a density measurement making it difficult to implement in real time on a continuous paving operation. Ground penetrating radar units can operate in a continuous fashion but are more expensive and the correlation between signal reflection and density on a hot asphalt mat have not been precisely determined. This paper presents a new type of asphalt pavement density for a roller operator's real time control of paving density that will be simpler, cheaper, and safer than existing density measurement techniques and provide a continuous assessment of pavement quality.

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DESCRIPTION

This asphalt pavement density indicator will be developed based on the continuous comparison of two microwave signals reflected by the pavement, one in front of the roller and one behind it (Figure 1). Horn antennas will be used to transmit and receive the microwave signals which will be coupled via a microwave bridge in order to continuously monitor the variability of the two reflected signals. In previous field studies, the research team found a decreasing trend in microwave signal variability as the density increases. Once the pavement reaches the optimal compaction level, the variance suddenly jumps. It is this information that is being used to determine that the optimal compaction range has been reached. By using this "differential approach" on the two microwave reflections of the proper frequency, the influence of a large number of parameters involved on which reflectivity of a pavement depends (e.g., permittivity and loss) will be minimized.

This idea operates by transmitting an amplitude modulated microwave signal from a low-power microwave oscillator via a directional coupler and circulator to the antenna horn pointed perpendicular to the asphalt pavement (Figure 2). This setup with horn antennas in front and behind the roller pick up the reflected

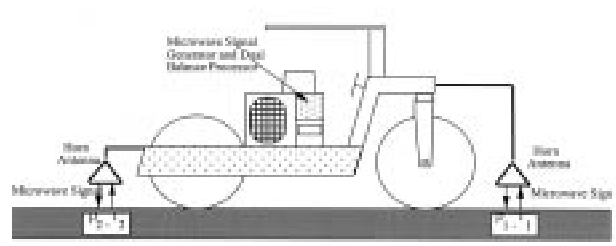

FIGURE 1 Real time microwave pavement sensor attached to a roller.

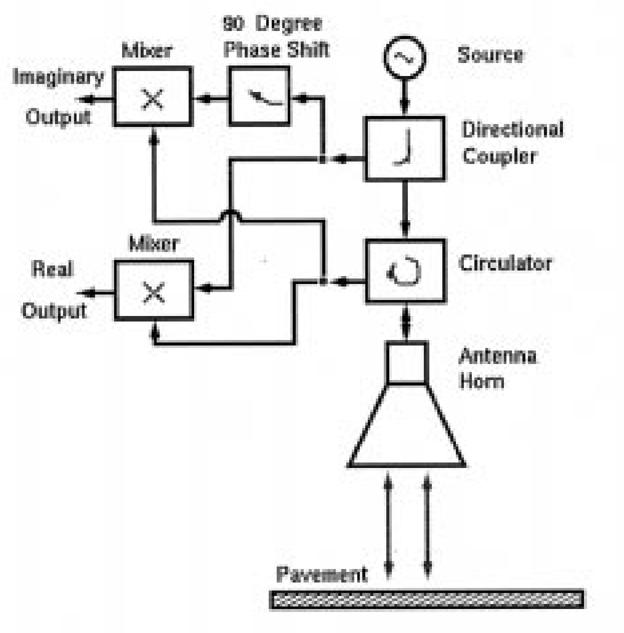

FIGURE 2 Schematic for real time microwave pavement sensor.

signals from the pavement, and transmit a real and imaginary output from each horn to a computer for processing.

PRELIMINARY FIELD TESTS

Field tests were conducted on two separate occasions to determine the feasibility of this idea. Both tests were funded by the Center for Advanced Technology and Development (CATD) at Iowa State University. The goal of this field testing was to be able to detect differences in microwave reflected signals for different compaction levels on hot asphalt. In the first field test conducted during May 1996, eleven different microwave signal frequencies were reflected off of a hot asphalt surface of varying density. Results from this test showed that a relationship was found between the reflected microwave signal and density. The variability of the reflected microwave signal was found to decrease as the density increased until the point of optimal compaction. At this point, there is a sharp increase in the variance of the reflected microwave signal. Results from the first set of field tests were verified during a second round of tests conducted in the fall of the same year.

PROTOTYPE DEVELOPMENT

The microwave horn antennas are mounted on carts (antenna platforms) attached to the breakdown roller with cantilevered arms. Each cart is equipped with a vibration dampening system to reduce the vibration from the roller. The set up is shown in Figure 3.

Many of the design constraints established for this project were based on what the research team found to work during the preliminary field testing stage. The design constraints used for the design of the prototype are as follows:

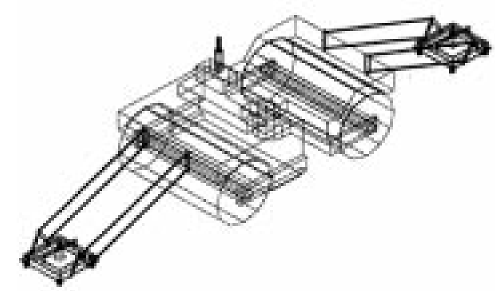

FIGURE 3 Equipment set-up.

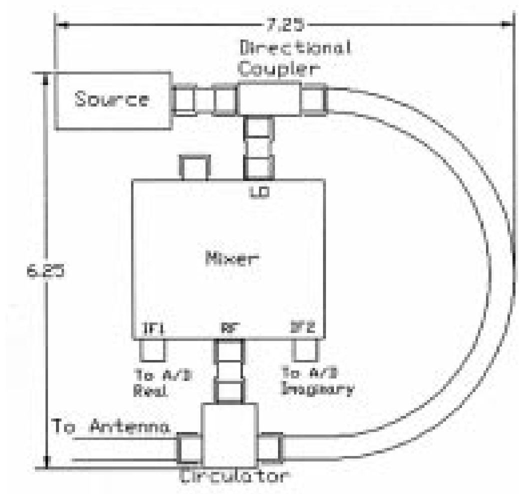

FIGURE 4 Microwave circuit (dimensions in inches).

- Antenna platform maximum weight = 30 lbs.
- Height of microwave antenna to be held constant at 15 cm.
- Microwave antenna should be 2 to 3m away from breakdown roller.
- Density readings to be taken at fixed distances of approximately 2 cm.

The prototype design consists of four components, listed below.

Microwave Signal Circuit

The final circuit design is shown in Figure 4.

Pneumatic System

Included in the design is a pneumatic system which will be used to remove water from the asphalt surface during compaction. Water used to lubricate the drums may pose a problem by distorting the return signal. It was decided to use a manual pneumatic spray approach for the initial tests whereby an air compressor and hose would be used to blow the water from the surface. In later versions, a spray attachments could be mounted on the carts. The research

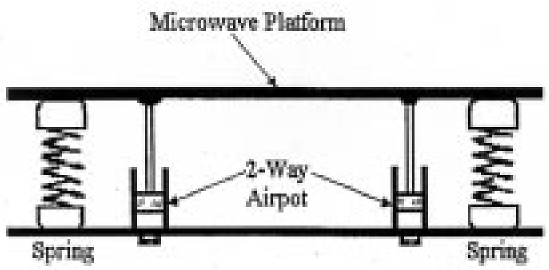

FIGURE 5 Mass-spring damper system.

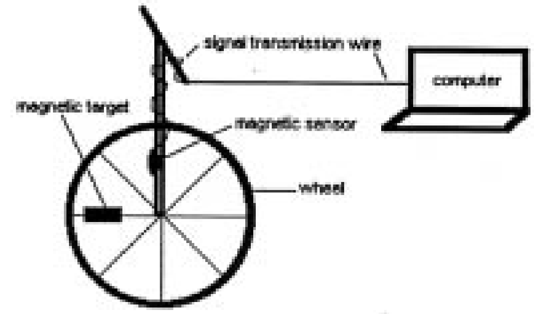

FIGURE 6 Magnetic field density method.

team conducted field tests that demonstrated that 100 psi is a suitable air pressure to remove water from the asphalt surface without damage.

Antenna Platform

The antenna platform has been designed using a two frame approach with vibration isolation devices connecting both frames. The upper frame holds the antenna and microwave equipment, while the lower platform rolls on the surface with special high temperature wheels and is connected to the roller. Vertical vibration dampening is achieved using a combination of springs and dashpots while a foam liner is used to dampen lateral vibration. A "Mass-Spring Damper System" as shown in Figure 5 provides a simple and low cost vibration control. Theoretical calculations as well as simulations were performed to determine the dampening coefficient needed on the springs and dashpots.

Signal Sampling Regulator

The signal sampling regulator is needed to trigger density samples measurements at discrete intervals. The design incorporates a "magnetic field density" approach as shown in Figure 6. The wheel, in contact with the rear roller wheel of the compactor, triggers a density reading each time the metal target is detected.

PROTOTYPE FIELD TEST RESULTS

The research team plans to conduct field tests on the prototype during the summer, 1998. These results are not available at this point in time but will be provided at the conference.

ANTICIPATED IMPACT TO PRACTICE

The novel approach described in this paper would have numerous applications. Asphalt paving contractors could deploy this device on their roller compactors and provide their operators with a better sense when optimal compaction in achieved. Transportation agencies will benefit from higher quality pavement and contractors will experience fewer penalties. It is anticipated that this asphalt pavement indicator will be simpler, cheaper, and safer than existing density measurement techniques and provide a continuous assessment of pavement quality.

CONCLUSIONS

This paper has discussed a novel approach to determine asphalt pavement density during the compaction process. This approach simultaneously compares the variability of microwave signals from the front and back of the breakdown roller. It was found in field tests that the variance of the microwave signal decreases as density increases and then sharply increases in the optimal compaction range. Results from the prototype field tests will be provided during the conference as they were not available at this time. It is anticipated that this method will become a widely used approach for determining asphalt pavement density.

ACKNOWLEDGMENTS

The authors acknowledge the National Academy of Sciences IDEA Program for funding this project. Also, we appreciate the contributions of our advisory committee members and the many students at Iowa State University who assisted in the development of this project.

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